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DRAWINGS ATTACHED

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(71) We, INDUSTRIAL NUCLEONICS CORPORATION, a corporation incorporated in 1969 and existing under the laws of the State of Ohio, United States of America, of 650 Ackerman Road, Columbus, Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to material manufacturing processes and more particularly to a method of and apparatus for evaluating the drying performance of a dryer in removing moisture from a material.

It has been difficult to estimate the drying performance of a dryer. Some prior systems have computed a figure for dryer efficiency from the amount of water removed relative to the amount of steam supplied to the dryer. Such a system is described in an article by E. S. Savas, "Computer Control in the Paper Mill", TAPPI Magazine, May 1964 (Pages 129A and 130A). U.S. Patent 2,767,484 issued on October 23, 1956 describes a method for regulating a dryer in accordance with the measured shrinkage occurring in the product being dried. A water removal control system for a paper making machine is described in U.S. Patent 2,922,475 issued on January 26, 1960. U.S. Patent 3,260,642, issued July 12, 1966, describes a system for controlling the steam supply to a dryer in accordance with the moisture content measured before and after the final dryer. None of these prior art methods provides a reliable indication of how well a dryer is performing in removing moisture from a product, particularly in the cross-machine direction.

The present invention provides a method of and apparatus for evaluating the performance of a dryer by comparing the moisture in the partially-dried product leaving the dryer with the moisture in the wet product entering the dryer.

The invention provides a method of evaluating the performance of a dryer in removing moisture from a moisture-laden material to provide a partially dried material, said method comprising the steps of: evaluating the pre-dryer moisture content of said moisture-laden material and obtaining a first signal indicative of any deviation of said moisture content from a first reference value therefor, the sense of said first signal depending on the relative magnitudes of the measured moisture content and said first reference value; measuring the post-dryer moisture content of said partially dried material and obtaining a second signal indicative of any deviation of said moisture content from a second reference value therefor, the sense of said second signal depending on the relative magnitudes of the measured moisture content and said second reference value; and comparing the senses of said first signal and said second signal to provide an output signal indicative of the relative senses of said first and second signals and hence indicative of the drying performance of said dryer.

The invention also provides apparatus for evaluating the performance of a dryer in removing moisture from a moisture-laden material to provide a partially dried material, comprising first means for evaluating the predryer moisture content of said moisture-laden material and for providing a first signal indicative of any deviation of said moisture content from a first reference value therefor, said first means including means for ascertaining the sense of said first signal

[*Price 25p*]

as dependent on the relative magnitudes of the measured moisture content and said first reference value; second means for measuring the post-dryer moisture content of said partially dried material and for providing a second signal indicative of any deviation of said moisture content from a second reference value therefor, said second means including means for ascertaining the sense of said second signal as dependent on the relative magnitudes of the measured moisture content and said second reference value; and third means responsive to said first signal and said second signal for producing an output indicative of the relative senses of said first and second signals and hence indicative of the drying performance of said dryer.

In a preferred form of apparatus, if the wet product enters the dryer with excess moisture and leaves with a moisture content below the post-dryer target, a "good" indication is registered. Conversely, if the product enters the dryer relatively dry and leaves wetter than the post-dryer target, a "poor" indication is registered. Any other set of conditions results in an "indeterminate" indication. A reliable index for measuring dryer performance is established.

With material in sheet form, and using scanning gauges movable across the sheet before and after the dryer, average sheet moisture values may be derived which provide the first and second reference values above referred to for each of a number of zones extending longitudinally of the sheet. In a preferred embodiment logic circuitry determines the sense of pre-dryer moisture content deviation from its average value relative to the sense of the post-dryer moisture content deviation from its average value and provides one of the above three indications of dryer performance on a display device.

In addition, the dryer performance profile, i.e., the operating performance of the dryer in zones across its width, may be evaluated and read out on a suitable indicator such as an array of colored lights or an x-y recorder. Operating personnel may conveniently monitor the operating of the dryer by observing the performance display provided. Manual or automatic correcting adjustments may be made to the dryer or other equipments when any deterioration from a desired performance is indicated.

The invention will be further described with reference to the accompanying drawings in which:—

Fig. 1 is a block diagram of an industrial sheet dryer showing moisture gauges and an associated data processing system for carrying out the method of the present invention;

Fig. 2 is a graph of drying curves illustrating contrasting dryer performance characteristics;

Fig. 3 is a plot of sheet moisture content measured in a cross-sheet direction, before and after the dryer, shown in Fig. 1;

Fig. 4 is a block diagram, partly schematic, of one type of data processor useful in the system shown in Fig. 1;

Fig. 5 is a block diagram of an alternative data processor.

Fig. 6 is a block diagram illustrating one method for indicating dryer performance profile; and

Fig. 7 is a block diagram of an alternative dryer performance profile indicator.

With reference now to Figs. 1 and 2, the present invention is described in connection with a paper sheet drying process but the technique may be applicable with substantially equal utility to other processes providing products of different composition and shape. For example, the invention may find application in those industries that treat materials with chemicals that are volatile such as impregnators or coaters. The material treated may also be in bulk form and transported by conveyors through a drying unit. The invention can be used in the manufacture of regenerated cellulose film, where solvents and water are removed from the films.

In a specific embodiment, a dryer 10 is illustrated and may comprise a steam heated dryer section, or press rolls, or any other unit for removing moisture from a moving sheet 12. The sheet 12 enters the dryer 10 at location A and leaves at location B. These may be referred to as the wet end and th dry end, respectively. The dryer 10 removes moisture from the entering sheet and provides a relatively dry sheet at the far end. For this purpose, the dryer 10 receives a supply of heat from unit 14 for the purpose of evaporating moisture such as water from the sheet 12 as it passes from left to right. Frequently, the dryer 10 is provided with a plurality of individual sections 10*a* which sections extend transversely of the direction of movement of a sheet through the dryer; each section serves to remove water from one of several zones of the sheet which zones are numbered from 1 to 8 and extend across the width of the dryer.

As a result of the addition of heat to the sheet, the moisture is reduced from a relatively high value at the wet end, A, to a low value at the dry end, B, as illustrated by the drying curves in Fig. 2. For example, the moisture content by weight at the wet end in a typical paper making process may approach 65 to 75 percent, while the moisture content by weight of the paper sheet leaving the dryer may be in the vicinity of 5 to 7 percent. The curves in Fig. 2 may be

representative of dryer operation along any selected zone 1 to 8.

The ordinates of the graph in Fig. 2 may be in units denoting the amount of moisture or water in the sheet 12. For example, such terms as "moisture content", "percent moisture", "absolute moisture content", are commonly used. It is convenient to refer to the actual amount of water in the sheet at the wet end as the load on the dryer. This may be expressed in units of pounds of water per square foot and is the factor which is examined and compared with the final sheet moisture to establish the dryer's performance.

Two different moisture loads may be equivalent to the same moisture content at the wet end, if the solid e.g. fiber content of the sheet changes. One may measure the percent moisture of the incoming sheet and use this parameter for comparison, if the weight of the solid e.g. fiber in the sheet remains substantially constant. In other words, under this condition, the moisture content at the wet end determines the load on the dryer. In this disclosure, the terms moisture content or water content are used synonomously hereinafter in referring to the load on the dryer and the percent moisture of the final sheet. The actual amount of water in the final sheet may be measured and compared with the amount at the wet end to obtain the desired performance index.

Since it is the actual amount of incoming water that the dryer must handle, it is useful to determine its response to a predetermined amount of moisture at the wet end. An acceptable performance results when the dryer encounters a relatively large amount of moisture at the wet end and delivers a sheet having a relatively low percent moisture. The dryer performs poorly when it produces a relatively wet sheet from one with relatively little moisture.

Very often the operation and general performance of the dryer 10 deteriorates due to mechanical malfunction or for example clogging that arises in the flow path of drying air. As a result, the performance of the dryer may vary considerably from time to time. Curves P and G graphically illustrate how the performance of the dryer may vary. Curve G starts at a relatively high moisture content or load and levels out at a relatively low moisture content and is therefore indicative of a good or acceptable drying performance. On the other hand, curve P starts at a relatively low wet-end moisture content or load and levels out at a final dry-end moisture content greater than curve G. Curve P is representative of a poor or unacceptable drying performance. The remaining curves are representative of two different cases wherein the performance is indeterminate.

An indication of dryer performance is obtained by comparing how the moisture content or load at the wet end deviates from a pre-dryer target T_A with how the moisture at the dry end deviates from a post-dryer target T_B. Signals S_A and S_B indicative of the sheet moisture at the wet end and at the dry end respectively, are computed by a computer 16 (see Fig. 1) from measurements made by gauges 18, 20 and 22 positioned before and after the dryer 10.

Gauge 18 measures the total weight per unit area of the wet sheet and gauge 20 measures the total weight per unit area of the partially dried sheet. The gauge 22 provides a signal proportional to the moisture content m_B of the partially dried sheet. Since the moisture content of the entering sheet is very high and not readily monitored reliably by present state-of-the-art moisture gauges, its value is determined by subtracting the weight per unit area of the dry sheet (i.e. the solid or fiber content) from the total weight per unit area of the wet sheet. The dry sheet weight per unit area will not usually vary substantially in the machine direction (i.e. the direction of movement of the sheet through the machine); its value will be

$$(1-\frac{m_B}{100})W_B$$

where W_B is the total weight per unit area of the partially dried sheet, and m_B is the % moisture in the partially dried sheet, expressed as the percent by weight of moisture compared with the weight of partially dried sheet. The pre-dryer moisture content of the sheet in pounds of water per pounds of wet paper, for example, is then

$$q_A=\frac{W_A-(1-\frac{m_B}{100})W_B}{W_A} \qquad (1)$$

where W_A is the total weight of the wet sheet entering the dryer 10. The moisture load W_w is

$$W_w=W_A-(1-\frac{m_B}{100})W_B \qquad (2)$$

Other approximations or simplifications may be made in the computation of W_w depending on the relative levels of moisture encountered for different processes and taking into account the degree of accuracy which is desired. Signals S_A and S_B are proportional to the quantities W_w and m_B. Alternatively, transducers other than weight gauges may be employed to derive the desired sheet moisture signals S_A and S_B.

The weight gauges 18 and 20 may preferably each comprise a nucleonic gauge of the type described in U.S. Patent 2,790,945. These gauges respond to radiation passed through the sheet 12 by a source of radiation and provide an output signal proportional to the weight of the sheet 12.

The moisture gauge 22 may take many forms, such as for example, a detector that responds to the reflection of thermalized neutrons directed at the sheet by the hydrogen atoms in the sheet moisture, a dielectric or capacitance gauge. A preferred capacitance moisture gauging system is described in U.S. Patent 3,155,901 and U.S. Patent 3,155,902. In such a system an electrode assembly is placed against the sheet and energized at one or more signal frequencies to provide an output signal proportional to the moisture content of the sheet 12 in the form of percent moisture by weight in the sheet.

The moisture signals S_A and S_B are supplied to a moisture data processing unit 24 which compares these signals with a pre-dryer target and a post-dryer target signal respectively, set in on lines 26 and 28. The target signals may be generated by a voltage divider circuit comprising a battery and a manually adjustable potentiometer and correspond to the values shown in Fig. 2. The construction of the data processor 24 will be described in detail hereinafter with reference to Figs. 4 and 5. The data processor 24 may employ digital or analog signal processing techniques to provide the desired output indication.

Briefly, the target signals are subtracted from the moisture signals S_A and S_B to obtain a pair of deviation signals. The relative sense of the deviation signals is measured by a phase sensitive circuit to provide an output signal representative of dryer performance.

A drying performance indicator 30 receives the output signal from the moisture data processor 24 to provide an output, such as a typewritten record or other visual display 30*a*.

The system of Fig. 1 operates generally in the following manner: The data processor 24 computes the deviation in moisture content from the preselected target for each location A and B. The sense of each moisture deviation relative to its target is determined. The sense of the pre-dryer deviation is then compared with the sense of the post-dryer deviation and the following rules of logic are observed. If the sense of the two deviations are the same, there is a positive correlation and no absolute information can be determined. This results in an indeterminate performance situation. In other words, no reliable indication of the dryer's operating performance is possible when the sense of the deviation at the dry end is the same as it is at the wet end.

If, however, there is a negative correlation between the sense of the post-dryer and sense of the pre-dryer deviations, i.e., they are in opposite directions, the data processor 24 generates either a "poor" drying signal or a "good" drying signal. A "good" drying signal is generated whenever the pre-dryer deviation in moisture or load is greater than target T_A and the post-dryer moisture deviation is less than target T_B. A poor dryer signal is generated whenever the pre-dryer deviation in moisture or load is less than target and the post-dryer moisture deviation is greater than target T_B. One or both moisture deviations may be equal to their respective target values, in which case, a "poor" indication may be made. As a rule, it is generally desirable to display a "good" performance only when it is clearly indicated.

Since it is desirable to know how the performance varies from zone-to-zone, a scanning controller 32 may be used to traverse the gauges back and forth across the width of the sheet 12 by means of motors 34 and 36. Alternatively, a plurality of gauges may be employed. The gauges may be maintained in synchronism to measure essentially the same longitudinal zone extending down the sheet in the machine direction. Alternatively, the signal from gauge 18 can be delayed and the gauges arranged to have computer 16 receive signals from the same measured area that are compared simultaneously, to eliminate the effect of transport distance between gauges 18 and 20. It is assumed that the weight per unit area of the dry sheet will remain substantially constant in the machine direction. A signal may be coupled from the scanning controller 32 to the data processor 24 over line 38 which is indicative of the cross-sheet position of the gauges. The gauge position signal may be used to synchronize the readout of indicator 30 with moisture measurements being made. This enables an indication of the dryer's performance along each of the respective zones 1—8. The indicator 30 may be provided with a separate display such as a red lamp 40 and a green lamp 42 to indicate either a poor or a good drying performance respectively for each zone.

Referring now to Figs. 3 and 4, since there may be a drift in sheet moisture over a period of time, the preselected targets T_A and T_B may not be representative. If fixed targets are employed, deviation signals of the same sense may result if the sheet moisture varies only in one direction from the target. Accordingly, it is preferred to average the sheet moisture content before and after the dryer and to use these values as the targets. Now, variations will occur on each side of

the average resulting in deviation signals that can vary in sign across the width of the sheet 12. Typical cross-sheet moisture variations or profile as viewed looking upstream are illustrated in Fig. 3. The respective pre-dryer and post-dryer averages are drawn in dotted lines 48 and 50. A graphical examination of the moisture profile drawn in Fig. 3 shows that three different types of dryer performance exist across the width of the sheet. The dryer performance is "indeterminate" in zones 1 and 2, "poor" in zones 3, 4 and 5, and "good" in zones 6, 7 and 8. This determination is made by observing the sense of the moisture deviations relative to the average values in accordance with the rules of logic stated above in reference to Figs. 1 and 2.

By observing the performance indication, the operator is continuously advised of the dryer's operation. He is able to locate malfunctions that detract from the dryer's performance. The operator can accordingly make adjustments to the dryer to optimize its drying performance. The profile indication particularly facilitates the adjustment of individual dryer sections 10*a*.

In Fig. 4, the moisture signals S_A and S_B from the moisture content computer 16 are coupled to a pair of averaging devices 52, 54 whose operation is controlled by the scanning controller 32. This enables the determination of the average moisture content each time the gauges scan across the sheet. The averaging devices 52, 54 are energized as gauges start at one side of the sheet and are deenergized when the gauges reach the opposite side of the sheet. The variations in sheet moisture content are measured during each scan. Reference may be had to U.S. Patent 3,015,129, for a more detailed description of the profile averaging technique described briefly herein.

Each averaging device 52, 54 may be provided with a signal holding or storage unit 52*a*, 54*a* which may store the computed scan average or other representative value for a period of one or more subsequent scans. During the measuring scans, the variations in cross-sheet moisture or water content are compared by means of comparators 56 and 58 with the stored value of cross-machine average sheet moisture. Comparator units 56 and 58 may be simply subtraction devices that provide an output signal proportional to the difference between two input signals. Comparator 56 provides an output signal W having a polarity in accordance with the sense of the deviation of the measured wet-end moisture content from the average signal stored by the signal holding or storage unit 52*a*. Comparator 58 provides an output signal D having a polarity indicative of the sense of the deviation of the measured dry-end moisture content from the average value stored by the signal holding or storage unit 54*a*.

The data processor 24 detects the polarity or sense and the magnitude of the deviation signals W and D. A typical data processing circuit 24 may include a pair of multipliers 60 and 62 and four diodes 63—66 coupling the multipliers to the wet and dry deviation signals W and D. The output of multiplier 62 is coupled directly to a summing amplifier 68. The phase inverting amplifier 70 couples the output of multiplier 60 to the input of the summing amplifier 68. An indicator 72 having a dial calibrated plus, zero and minus serves to indicate whether the performance of the dryer 10 is acceptable. indeterminate or unacceptable respectively. Other sense comparison circuits such as phase detectors may be employed instead to respond to the respective polarities of the signals W and D and provide one of the three alternative indications of dryer performance.

A quantitative indication of how well or how badly the dryer is performing may be obtained by examining the amplitude of the signal provided by amplifier 68. Accordingly, an amplitude detector 71, such as a linearizing square root computer, may be employed to provide an output signal which is proportional to the relative amplitude of the summed deviation signals W and D. A separate meter 73 may be used to visually indicate the amplitude of this output signal. Alternatively, one meter may be constructed to accomplish the function of both of the meters 72 and 73. Other amplitude responsive circuits and display units will be apparent to those skilled in the art.

The operation of the embodiment of the present invention proceeds as follows: the scanning controller 32 energizes the traversing motors 34 and 36 (see Fig. 1) to move the weight and moisture gauges across the sheet from one side to the other. The operation is first described in terms of a single point performance gauge thereby facilitating the explanation of the later extension to a profile readout. The automatic scanning routine of the scanning controller may be interdicted by a single point selector unit 74. This may be done by an operator selecting one of the single point positions 1 to 8 by means of a control knob 76 coupled to the selector unit 74 connected to the scanning controller. For purposes of illustration, if it is assumed that zone 4 is to be monitored, the gauges will automatically position themselves along this machine direction zone. The variations in moisture content at both the wet and the dry end are averaged by the averaging devices 52 and 54. When the far side of the sheet is reached, the scanning controller 32 stops the movement of the gauges as well as the

averaging of the moisture signals. The gauges are automatically returned to the opposite side of the sheet to start a new scan. The moisture signals developed during the next scan are compared by comparator units 56 and 58 with the average values computed for the preceding scan and stored by units 52*a* and 54*a*.

For purposes of illustration, assume a first condition where the moisture content of the sheet entering the dryer is relatively high, at least greater than the average cross-sheet value of the moisture content. Furthermore, let us assume that the moisture content of the sheet leaving the dryer is less than the post-dryer average moisture content. Under these conditions, when the gauges reach zone 4, the moisture signal on line 78 connected to the positive input in comparator 56 will be greater than the average value retrieved from averaging device 52. This results in a deviation signal W having a positive polarity. Since the post-dryer moisture content is relatively small, the signal on line 80 connected to comparator 58 will be less than the average signal retrieved from averaging device 54. This results in a post-dryer deviation signal D which has a negative polarity.

By virtue of the polarizing effect of the diodes 63—66, it is apparent that the multiplier 60 receive a voltage on both input terminals, one of one polarity and another of the opposite polarity. The product developed by multiplier 60 will be of negative polarity which is reversed by the phase-reversing amplifier 70. Since there is no output from multiplier 62, due to back-biasing of diodes 65 and 66, summing amplifier 68 develops a positive-going output signal. The dryer 10, at least along zone 4, is operating according to curve G shown in Fig. 2, which is an acceptable performance and which is reflected by the positive indication upon indicator 72.

If, on the other hand, the moisture content at the wet end is less than the average value stored in averaging device 52*a* and the moisture content at the dry end is greater than the average value stored in the averaging device 54*a*, the polarity of the deviation signals W and D developed by comparators 56 and 58, respectively, will be reversed from what they were in the previous example. In this case, the wet-end deviation signal W will be negative and the dry-end deviation signal D will be positive. Signals of this polarity are conducted only by diodes 65 and 66. Therefore, only multiplier 62 receives input signals to form a product on line 82. The polarity of this product is negative. Since only one input signal is provided to the summing amplifier 68, its output will be negative in polarity and the indicator 72 will register an unacceptable performance for the dryer 10.

In each of these two cases, meter 73 reflects the degree to which the performance is acceptable (or unacceptable). The quality of performance is directly proportional to the magnitude of the signals W and D. For example, if their magnitudes are relatively large, the performance indicated is very good or very poor depending on their respective polarities.

If both the pre-dryer moisture content and the post-dryer moisture content are greater than the averages computed by averaging devices 52 and 54, respectively, it can be seen that the deviation signals W and D will have a positive polarity. Conversely, if the pre-dryer and post-dryer moisture contents are less than their respective average values, then the deviation signals W and D will both have a negative polarity. In either case, each multiplier receives only one input voltage. Since there is zero voltage on the other input to the multipliers, the computed product is zero. (It will be seen that the multipliers act as AND gates.) This indication is made upon indicator 72, reflecting an indeterminate dryer performance. In this case, no indication is made upon meter 73.

Instead of evaluating only one zone along the sheet, it may be desirable to use a plurality of indicators 72 and 73, one set for each zone. The control knob 76 may be moved to an AUTO mode whereby the scanning controller 32 continually moves the gauges back and forth across the sheet and the meters 72 are automatically switched to data processor 24 to indicate the performance of the dryer 10 along each of the zones 1—8. Means may be provided to maintain the readings of each indicator while the gauge scans past a particular zone and until it returns on the following scan. This signal-holding means will be apparent to those skilled in the art. It may be desirable to compute the average moisture content across the sheet only once every several scans, depending on how frequently the moisture content varies in the machine direction. How often the average must be updated will be a function of the particular process being monitored.

Alternative forms of data processing and display are illustrated in Figs. 5, 6 and 7.

With reference now to Fig. 5, it may be desirable to use a green lamp 84, a yellow lamp 86 and a red lamp 88 to indicate an acceptable, an indeterminate, or an unacceptable dryer performance respectively. These indicator lamps are coupled by diodes 90—93 to the deviation signals W and D by way of AND circuits 94 and 96 and a NOR circuit 98. The output of AND circuit 94 is connected to the green indicator lamp 84

and to one input of NOR circuit 98. The output of AND circuit 96 is connected to the red indicator lamp 88 and to the other input of NOR circuit 98. The output of the NOR circuit 98 is connected to the yellow indicator lamp 86. The AND and NOR circuits are well known to those skilled in the art. It may be necessary to employ inverter circuits I_1 and I_2 if AND circuits 94 and 96 accept only input signals having the same polarity. The operation of this circuit may be examined along the lines used in explaining the circuit in Fig. 4. For example, if the dryer performance is acceptable, the wet-end deviation signal W will be positive and the dry-end deviation signal D will be negative. This results in signals applied simultaneously to the AND circuit 94. AND circuit 94 provides an output signal which energizes the green indicator lamp 84.

If the dryer performance deteriorates, the wet-end deviation signal W will be negative and the dry-end deviation signal D will be positive, causing AND circuit 96 to energize the red indicator lamp 88.

If, on the other hand, deviation signals W and D have the same polarity, each AND circuit will receive only one input signal and therefore fail to energize either the green or the red indicator lamps. Since NOR circuit 98 receives no signal on either of its inputs, it will provide an output signal energizing the yellow indicator lamp 86, reflecting the indeterminate dryer performance.

Of course, if more than one zone across the sheet must be monitored, a bank of indicator lights may be automatically switched in to the logic circuitry in accordance with the position of the gauges across the sheet.

In some cases, it may be more desirable to use a chart recorder such as shown in Fig. 6 to indicate the performance profile for the dryer 10. In this alternative embodiment, a marking indicator 100 is coupled to the scanning controller 32 so that its lateral position from left to right across the chart 102 is indicative of the position of the scanning gauges across the width of the sheet 12. This may simply be a slidewire coupled to the gauge positioning servo circuits used in the scanning controller unit 32. The recorder scale 103 may be labeled to designate the cross-sheet zones 1—8.

A chart drive unit 104 receives signals from the AND and NOR circuits shown in Fig. 5, and translates these into a rotation displacement of a chart roll 106. For example, the signal from the AND circuit 94 may be connected to an input 104*a* to cause the chart drive to rotate the drive roll 106 to move the chart 102 down. The output signal from the AND circuit 96 may be coupled to input terminal 104*b* and used to rotate the chart roll 106 in the opposite direction through a fixed angular displacement. The output signal from the NOR circuit 98 is connected to input line 104*c*, which keeps the chart roll 106 in the center of its angular displacement range. The trace made by marking indicator 100 upon chart 102 may be interpreted as follows: a trace falling below a base line 108 is indicative of a deteriorated performance, and a trace falling above the base line is indicative of an acceptable performance. It may be noted that an acceptable performance signal provided by AND circuit 94 will move the chart 102 down causing the drawn trace to fall above the base line 108. The converse is true if an unacceptable performance signal is developed by AND circuit 96 on line 104*b*. An output signal from the NOR signal will of course maintain the indicator 100 along the base line 108 which is drawn when the gauges return after each scan from one side of the sheet to the other. At the end of every scan of the sheet a scan index unit 110 may be used to cause the chart drive 104 to rotate the drive roll 106 through a relatively large angular displacement to move the chart down to separate the individual scan traces. Reference may be had to U.S. Patent 3,108,844 for a more detailed description of x—y profile readout circuitry.

What is provided is an x—y profile indication of the performance of the dryer across the width of the sheet. Alternatively, instead of causing the chart roll 106 to step up and down in accordance with the signals provided by the AND circuits 94 and 96, it may be more desirable to employ a pair of pens containing colored inks to distinguish between the dryer performance conditions. Referring to Fig. 7, a chart recorder 114 is provided with a green pen 116 and a red pen adjacent to it and not shown, each pen being individually positioned against the surface of the chart. The green pen 116 may be energized by a green pen selector 120 connected to the output of AND circuit 94. A red pen selector 122 may be coupled to the output of AND circuit 96 to position the red pen against the chart. The pens may be mounted on one housing movable simultaneously with the gauges as described above in reference to Fig. 6. A green trace upon the chart is indicative of an acceptable performance for the zones through which it is drawn. In the absence of a signal from either of the AND circuits 94 and 96, neither pen is positioned on the chart and a gap or space 124 will be indicative of an indeterminate dryer performance for those zones where the gap exists. Chart drive and indexing units 126 and 128 may also be employed.

Other circuits for electronically processing the moisture data signals and displaying the performance indices for the operator will

be apparent to those skilled in the art.

For example, in certain applications it may be necessary to use a delay network 130 (see Fig. 4) to delay the pre-dryer signal so that signals representative of the same area of the sheet are compared.

It may also be desirable to use signal amplitude limiters 132 and 134 (see Fig. 5) to prevent saturating the logic circuits. Other techniques for processing the derived deviation signals W and D prior to the AND circuits will be apparent to those skilled in the art.

The profile deviation signals W and D may be recorded directly on a chart for the operator to visually compare and interpret. Regardless of the type employed, the dryer performance display facilitates the manual or automatic adjustment of a valve V (see Fig. 1) coupling the heat supply 14 to the dryer 10 to maintain an economically desirable performance. Individual valves which correspond to the zones of the sheet may be used to control the performance profile of the dryer 10.

WHAT WE CLAIM IS:—

1. A method of evaluating the performance of a dryer in removing moisture from a moisture-laden material to provide a partially dried material, said method comprising the steps of: evaluating the pre-dryer moisture content of said moisture-laden material and obtaining a first signal indicative of any deviation of said moisture content from a first reference value therefor, the sense of said first signal depending on the relative magnitudes of the measured moisture content and said first reference value; measuring the post-dryer moisture content of said partially dried material and obtaining a second signal indicative of any deviation of said moisture content from a second reference value therefor, the sense of said second signal depending on the relative magnitudes of the measured moisture content and said second reference value; and comparing the senses of said first signal and said second signal to provide an output signal indicative of the relative senses of said first and second signals and hence indicative of the drying performance of said dryer.

2. A method according to claim 1 wherein said first and second signals are compared to provide one such output signal when said pre-dryer moisture content is greater than said first reference value therefor and said post-dryer moisture content is less than said second reference value therefor, and a second such output signal when said pre-dryer moisture content is less than said first reference value therefor and said post-dryer moisture content is greater than said second reference value therefor.

3. A method according to claim 1 or claim 2, further comprising the steps of computing the average moisture content of said moisture-laden material, and computing the average moisture content of said partially-dried material, said average moisture contents providing said first and second reference values.

4. A method as claimed in any of the preceding claims, wherein the moisture contents of said moisture-laden material and of said partially dried material are measured at a plurality of locations across the width of the material to provide said first and second signals for each location, and the said first and second signals are compared to derive a said output signal indicative of the relative senses of said signals and hence of the drying performance of said dryer, for each of the corresponding locations.

5. A method according to any of the preceding claims, further comprising the step of deriving from said first and second signals an output signal having a magnitude indicative of the quality of said dryer performance.

6. Apparatus for evaluating the performance of a dryer in removing moisture from a moisture-lader material to provide a partially dried material, comprising first means for evaluating the pre-dryer moisture content of said moisture-laden material and for providing a first signal indicative of any deviation of said moisture content from a first reference value therefor, said first means including means for ascertaining the sense of said first signal as dependent on the relative magnitudes of the measured moisture content and said first reference value; second means for measuring the post-dryer moisture content of said partially dried material and for providing a second signal indicative of any deviation of said moisture content from a second reference value therefor, said second means including means for ascertaining the sense of said second signal as dependent on the relative magnitudes of the measured moisture content and said second reference value; and third means responsive to said first signal and said second signal for producing an output indicative of the relative senses of said first and second signals and hence indicative of the drying performance of said dryer.

7. Apparatus as claimed in Claim 6, wherein said third means is adapted to produce an output in the form of one of three possible indications, namely, a first indication when said pre-dryer moisture content is greater than said reference value therefor and said post-dryer moisture content is less than said reference value therefor, a second indication when said pre-dryer moisture content is less than said reference value therefor and said post-dryer moisture content is greater than said reference value therefor

and a third indication when neither the first nor the second indication is appropriate.

8. Apparatus as claimed in Claim 7, including an array of coloured lights to receive the output of the third means, whereby a different coloured light is illuminated for each of said three indications.

9. Apparatus as claimed in any of Claims 6 to 8, including means to compute the average moisture content of said moisture-laden material, and the average moisture content of said partially-dried material, said average moisture contents providing said first and second reference values.

10. Apparatus as claimed in any of the preceding claims 6 to 9, wherein said first and second means are adapted to measure the moisture contents respectively of said moisture-laden material and of said partially-dried material at a plurality of locations across the width of the material to provide said first and second signals for each location, and said third means is responsive to the said first and second signals for producing an output indicative of the relative senses of said signals and hence of the drying performance of said dryer, for the corresponding locations.

11. Apparatus as claimed in any of the preceding claims 6 to 10 further comprising means for deriving from said first and second signals an output signal having a magnitude indicative of the quality of said dryer performance.

12. Apparatus for evaluating the performance of a dryer in removing moisture from a moisture-laden material to provide partially dried material, comprising first gauge means for evaluating the pre-dryer moisture content of said moisture-laden material and providing a signal dependent thereon; second gauge means for measuring the post-dryer moisture content of said partially dried material and providing a signal dependent thereon; means for computing the average moisture content of said moisture-laden material and the average moisture content of said partially dried material to provide first and second moisture reference values; and means for computing the difference between said first gauge signal and said first reference signal and between said second gauge signal and said second reference signal to provide a first and a second difference signal, respectively, and means responsive to the polarity of said first difference signal relative to said second difference signal for producing an output indicative of the drying performance of said dryer.

13. Apparatus as claimed in Claim 12, wherein the average computing means receive inputs from the first and second gauge means respectively.

14. Apparatus as claimed in Claim 12 or Claim 13, wherein said polarity responsive means comprises:

logic circuit means for providing a first performance indication when said difference signals are of the same sign, a second performance indication when said first difference signal has one sign which is different from that of said second difference signal, and a third performance indication when said first difference signal has the other sign which is different from that of said second difference signal.

15. Apparatus for evaluating the performance of a dryer in removing water from a longitudinally moving moisture-laden sheet to provide a partially dried sheet, comprising first gauge means for evaluating the pre-dryer moisture content of said moisture-laden sheet and providing a signal dependent thereon; second gauge means for measuring the post-dryer moisture content of said partially dried sheet and providing a signal dependent thereon; scan average computing means for providing a first average signal proportional to the average moisture content of said moisture-laden sheet over the width thereof and a second average signal proportional to the average moisture content of said partially dried sheet over the width thereof, means for computing the difference between said first gauge signal and said first average signal and between said second gauge signal and said second average signal to provide a first and second difference signal respectively, and means for comparing the sense of said first difference signal with the sense of said second difference signal to provide an indication of the drying performance of said dryer for zones of the sheet extending down the length thereof.

16. Apparatus as claimed in Claim 15, further comprising means to display the performance of the dryer according to the indications of said comparing means.

17. Apparatus as claimed in Claim 16, wherein the performance display means comprises a bank of indicators one for each zone.

18. Apparatus as claimed in Claim 16, wherein the performance display means is a chart recorder providing an x—y plot of the indication of said comparing means.

19. A method of evaluating the performance of a dryer in removing moisture from a moisture-laden material, substantially as herein described with reference to the accompanying drawings.

20. Apparatus for evaluating the performance of a dryer in removing moisture from a moisture-laden material, substantially as herein described with reference to the accompanying drawings.

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1247891 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

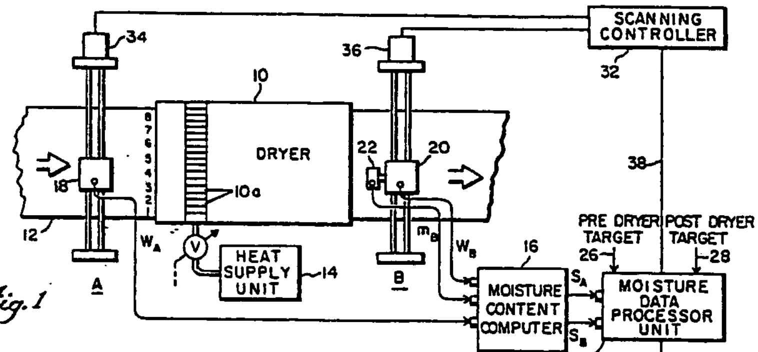

Fig. 1

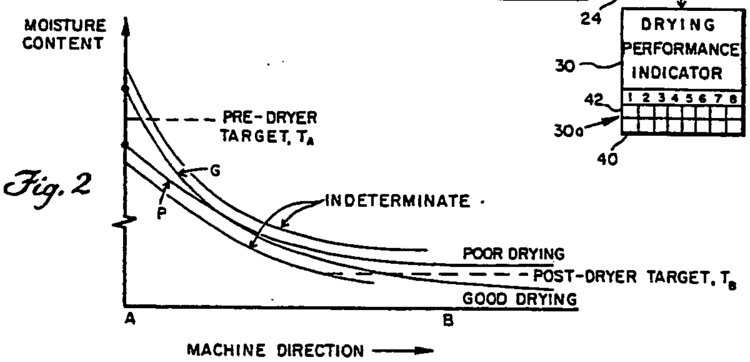

Fig. 2

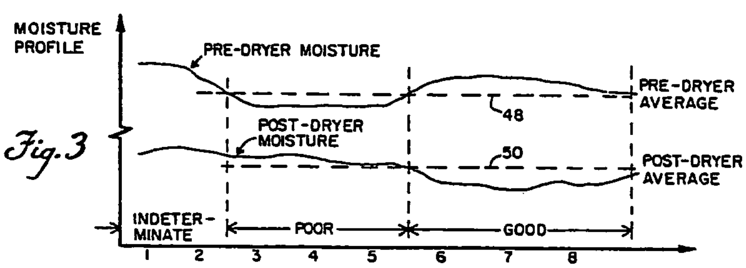

Fig. 3

1247891 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

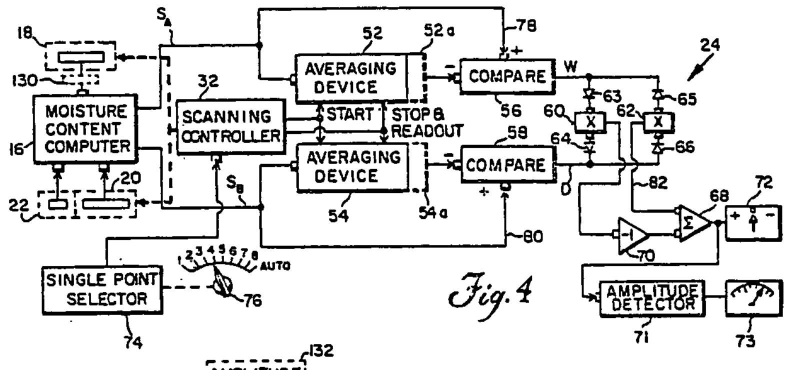

Fig. 4

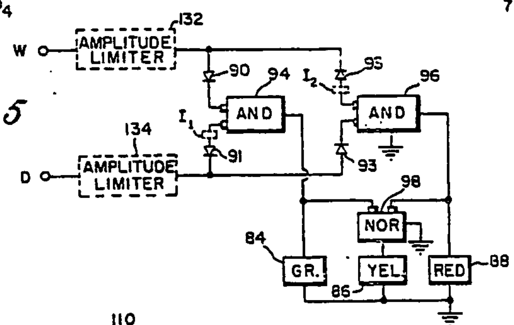

Fig. 5

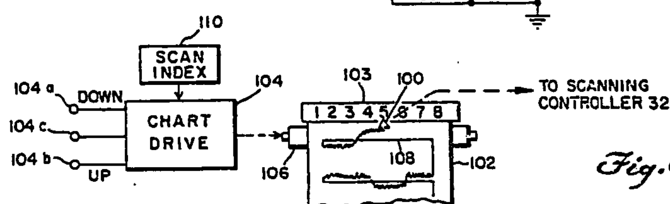

Fig. 6

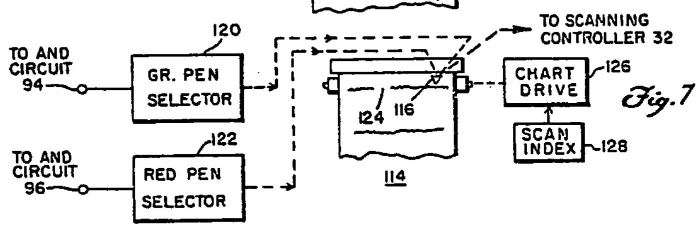

Fig. 7